# ORTHOGONAL FREQUENCY DIVISION MULTIPLEX MODEM CIRCUIT

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to an orthogonal frequency division multiplex modem circuit, and in particular, to an OFDM (Orthogonal Frequency Division Multiplex) modem circuit which transmits a plurality of different channels.

### Description of the Related Art

In recent years, the digitization of broadcasting has been promoted and an OFDM system will be adopted as its modulation system. Moreover, also in a 5-GHz-band wireless LAN (Local Area Network), the OFDM system is adopted as a modulation system.

The OFDM system is a system that divides a transmission signal into pieces, and modulates and transmits a plenty of subcarriers respectively, and has characteristics that the OFDM system has high frequency utilization efficiency and is strong on multi-path fading.

FIG. 10 shows an example of the structure of a conventional orthogonal frequency division multiplex modem circuit. A principle of the above-described OFDM system will be explained with using FIG. 10. First, a transmission signal X is a signal for, for example, digital high-definition television broadcasting, and consists of a 20-Mbps data signal and a 10.72-Mbps overhead (signal for error correction and synchronization

control). That is, the transmission signal X is 30.72 Mbps in total.

A 4×512-bit parallel data is generated by passing this signal through a serial/parallel converter (S/P) 101, and the data is divided every 4 bits. Owing to this, a 16-value QAM (QuadratureAmplitudeModulation)basebandsignalAisgenerated.

The 16-value QAM baseband signal A is complex data having a real part (Re) and an imaginary part (Im). Correspondence between each signal point on a complex plane and a 4-bit input signal is shown in FIG. 11.

Owing to this, 512 complex 16-value QAM signals A, each ofwhosesymbolratesis30.72/4/512Msps=15ksps,areoutputted. When these 512 complex numbers are inputted into an inverse Fouriertransformer(IFFT)105,512setsoftransformationresults B are obtained. These results B are converted into a serial signal C with a parallel/serial converter (P/S) 106.

Withmaking real parts before transformation be an I signal and making imaginary parts be a Q signal, these signals are outputted to a transmitter (TX) 107 at a sample rate of 15 ksps ×512 = 7.68 Msps. The transmitter 107 performs the orthogonal modulation of the I and Q baseband signals, and outputs them from an antenna 115.

The allocation of the subcarriers in a transmitter signal is shown in FIG. 12. As shown in FIG. 12, each interval between subcarriers is equal to the symbol rate of 15 kHz and the number of subcarriers is 512. Therefore, bandwidth is 15 kHz×512 = 7.68 MHz.

Next, the structure of a receiving side will be described. In the receiving side, a high frequency signal transmitted from the transmitting side is received with an antenna 116, a receiver (RX) 108 performs an orthogonal demodulation to generate a baseband signal (I, Q) D. A serial parallel converter (S/P) 109 samples this signal at the rate of 7.68 Msps respectively, and generates a parallel signal E consisting of 512 sets of I (real part) and Q (imaginary part) signals. When this signal is inputted into a discrete Fourier transformer (FFT) 110, 512 complex numbers are obtained.

This data F expresses a signal point of each corresponding sub carrier on a complex plane. A corresponding 4-bit data (in the case of a 16-value QAM) is reproduced from this signal point, and is decoded into the original signal Y and outputted with a parallel/serial converter (P/S) 112.

As described above, the bit rate transmitted in the OFDM system is very high-speed, for example, 30.72 Mbps. This is divided into many subcarriers and transmitted. When the number of subcarriers is 512 and a modulation system is the 16-value QAM, a symbol rate per sub carrier becomes only 15 ksps. The duration per one symbol is about 67•sec, and this is a sufficiently large value (this is equivalent to 20 km) in comparison with the path difference of a usual multi-path. Therefore, the OFDM system has powerful resistance to multi-path transmission.

The OFDM system is now planned with premising the utilization of each single unit such as digital television broadcast and high-speed wireless LAN equipment. However, since the OFDM system has a feature of being essentially strong on the multi-path

transmission, this feature is attractive also in other mobile communications.

Therefore, as a natural conclusion, it can be thought that demands for using the OFDM system also for mobile communications come out. However, since the OFDM system realizes vast transmission capacity as a whole by using hundreds of subcarriers, it is not allowed to use this monopolistically by one kind of mobile communication.

Therefore, it is possible to transmit various communications, such as digital TV, wireless LAN, the Internet, and cellular phones, via one OFDM line. The plural kinds of communication signals have different bit rates respectively, and their necessary transmission quality (QoS: Quality of Service) are different according to informational types.

That is, there are various transmission rates (for example, 28.8 kbps, 1.44 Mbps, and 10 Mbps) in data communication, and, an error rate not higher than 10E-6 is required. On the other hand, in speech communication such as a telephone, a transmission rate is 13 kbps or the like, and the error rate of 10E-3 is regarded as sufficient quality.

## SUMMARY OF THE INVENTION

Then, an object of the present invention is to solve the above-described troubles, and to provide an orthogonal frequency division multiplex modem circuit which can multiplex signals, whose bit rates and QoS are different from one another, and can transmit the signals via one OFDM line.

An orthogonal frequency division multiplex modem circuit according to the present invention is an orthogonal frequency division multiplex modem circuit that uses a plurality of subcarriers for communication, and transmits and receives a plurality of communication channels. In the circuit, each of a plurality of sub carrier groups into which the plurality of subcarriers is divided is assigned to each of the plurality of communication channels.

That is, the orthogonal frequency division multiplex modem circuit according to the present invention provides a method for multiplexing and transmitting a plurality of communication channelswhosebitratesandQoS (Qualityof Service) aredifferent from one another, via one OFDM (Orthogonal Frequency Division Multiplex) line.

In order to achieve this, a first orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that performing communications with using a plurality of subcarriers, dividing the plurality of subcarriers into a plurality of groups in an OFDM system whichtransmitsandreceivesapluralityofcommunicationchannels, and assigning the sub carrier groups to the plurality of communication channels respectively.

A second orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that the assignment of sub carrier groups to respective communication channel is adaptively performed.

A third orthogonal frequency division multiplex modem circuit according to the present invention is characterized

in that a modulation system given to each of the sub carrier groups is changed according to the QoS (Quality of Service) needed for a corresponding communication channel.

A fourth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that means for randomizing the alignment of the respective subcarriers on a frequency axis is included in a transmitting side, and that means for de-randomizing the alignment is included in a receiving side.

A fifth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that all subcarriers are assigned to a single channel as required, while communication of other channels is stopped.

A sixth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that the changeable modulation system that is described above uses phase modulation such as BPSK (Binary Phase Shift Keying), QPSK (Quadrature Phase Shift Keying), and QAM (Quadrature Amplitude Modulation), and a symbol point on a phase plane is changed according to the QoS.

A seventh orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that, since it is desirable for the transmitted power of each sub carrier to be uniform, a peak value of each modulation symbol is determined so that the transmission power of the respective subcarriers may become the same irrespective of the modulation system.

An eighth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that the processing for randomizing positions of respective subcarriers is updated every symbol as means for preventing the suppression of a specific sub carrier caused by frequency-selective fading.

A ninth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in comprising means for determining a randomization pattern every symbol and transmitting the randomization pattern every symbol to the receiving side is included in the transmitting side, and means for synchronizing transmission and reception of the randomization pattern is included.

A tenth orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that the orthogonal frequency division multiplex modem circuit comprises means for determining a randomization pattern every symbol and transmitting the randomization pattern every symbol to the receiving side is included in the transmitting side, and that a predetermined communication channel and a sub carrier corresponding to it are assigned as the means for synchronizing transmission and reception of the randomization pattern.

An eleventh orthogonal frequency division multiplex modem circuit according to the present invention is characterized in that a predetermined communication channel and a sub carrier corresponding thereto is excluded from randomization process.

Owing to the above-described structure and processing operation, the orthogonal frequency division multiplex modem

circuits of the present invention can transmit communication channels whose bit rates and QoS are different from one another with using one OFDM line.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the structure of an orthogonal frequency division multiplex modem circuit according to an embodiment of the present invention;

FIG. 2 is a block diagram showing a structural example of the serial/parallel converter shown in FIG. 1;

FIG. 3 is a block diagram showing a structural example of the serial/parallel converter shown in FIG. 1;

FIG. 4 is a diagram for explaining the randomizer of FIG. 1;

FIG. 5 is a diagram for explaining the de-randomizer of FIG. 1;

FIG. 6 is a time chart showing the operation of the serial/parallel converter of FIG. 2;

FIG. 7 is a time chart showing the operation of the serial/parallel converter of FIG. 3;

FIG. 8 is a graph showing symbol points on a complex plane;

FIG. 9 is a block diagram showing the structure of an orthogonal frequency division multiplex modem circuit according to another embodiments of the present invention;

FIG. 10 is a block diagram showing the structure of a orthogonal frequency division multiplex modem circuit according to a conventional example;

FIG. 11 is a graph showing correspondence of respective signal points on a complex plane, and 4-bit input signals; and

FIG. 12 is a diagram showing the allocation of subcarriers in a transmitter signal.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

Next, embodiments of the present invention will be described with reference to drawings. FIG. 1 is a block diagram showing the structure of an orthogonal frequency division multiplex modem circuit according to an embodiment of the present invention. In FIG. 1, the orthogonal frequency division multiplex modem circuit according to this embodiment of the present invention comprises a transmitting side consisting of serial/parallel converters (S/P) 101, 102, and 103, a randomizer 104, a discrete inverse Fourier transformer (IFFT) 105, a parallel/serial converter (P/S) 106, and a transmitter (TX) 107, and a receiving side consisting of a receiver (RX) 108, a serial/parallel converter (S/P) 109, a discrete Fourier transformer (FFT) 110, a de-randomizer 111, and parallel/serial converters (P/S) 112, 113, and 114.

FIG. 2 is a block diagram showing a structural example of the serial/parallel converter 101 shown in FIG. 1. In FIG. 2, the serial/parallel converter 101 consists of a shift register 601 and 16-value QAM (Quadrature Amplitude Modulation) generating circuits 602, 603, 604, and 605.

FIG. 3 is a block diagram showing a structural example of the serial/parallel converter 102 shown in FIG. 1. In FIG. 3, the serial/parallel converter 102 consists of a shift register

701 and QPSK (Quadrature Phase Shift Keying) generating circuits 702, 703, 704, and 705.

FIG. 4 is a drawing for explaining the randomizer 104 shown in FIG. 1, and FIG. 5 is a drawing for explaining the de-randomizer 111 shown in FIG. 1. FIG. 6 is a time chart showing the operation of the serial/parallel converter 101 shown in FIG. 2, and FIG. 7 is a time chart showing the operation of the serial/parallel converter 102 shown in FIG. 3. In addition, FIG. 8 is a graph showing symbol points on a complex plane. With reference to these FIGS. 1 to 8, the operation of the orthogonal frequency division multiplex modem circuit according to this embodiment of the present invention will be described.

Differently from the conventional example of the orthogonal frequency division multiplex modem circuit shown in FIG. 10, the orthogonal frequency division multiplex modem circuit according to this embodiment of the present invention has a plurality of data inputs X1, X2, ..., Xn in the transmitting side, and has a plurality of data outputs Y1, Y2, ..., Yn, corresponding thereto, also in the receiving side.

The input signals X1, X2, ..., Xn are converted into a complex parallel signal A with the serial/parallel converters 101, 102, and 103 respectively. For example, the input signal X1 is inputted at the bit rate of 240 kbps. If the QoS of the input signal X1 is a middle degree, four subcarriers are assigned, and an output of the serial/parallel converter 101 becomes four complex numbers (it corresponded to four subcarriers) at 15 ksps in the case that a modulation system is the 16-value QAM,

Intheserial/parallelconverter101generatingthe16-value QAM, as shown in FIG. 2, data is inputted into the shift register 601 driven by a clock having a frequency equal to the data rate. The 4-bit parallel outputs of the shift register 601 are a group at a time, and are inputted into the 16-value QAM generating circuits 602,603,604,605 respectively to be incorporated with a clock (Symbol CLOCK) equal to the symbol rate.

According to each incorporated 4-bit value, a symbol point on a complex plane as shown in FIG. 11 is chosen, and each real part (Re) and imaginary part (Im) are outputted. FIG. 6 shows a timing chart of the operation.

When the bit rate is 120 kbps and QoS is high, four subcarriers are assigned to the input signal X2 and the QPSK with a low error rate is used as a modulation system. In this case, an output of the serial/parallel converter 102 also becomes four complex numbers at 15 kbps (it corresponded to four subcarriers).

In the serial/parallel converter 102, as shown in FIG. 3, data is inputted into the shift register 701 driven with a clock having a frequency equal to a data rate. An parallel output of the shift register 701 is set every 2 bits, and is inputted into the QPSK generating circuits 702, 703, 704, and 705 respectively to be incorporated with a clock (Symbol CLOCK) equal to a symbol rate.

According to the incorporated value of 2 bits, a symbol point on a complex plane as shown in FIG. 8 is chosen, and each real part (Re) and an imaginary part (Im) are outputted. A timing chart of the operation is shown in FIG. 7.

Similarly, if the QoS of the input signal Xn is not so high and its bit rate is 90 kbps, a sub carrier is assigned. In addition, when a modulation system is a 64-value QAM, an output of the serial/parallel converter 103 also becomes one complex number at 15 ksps (it corresponded to one sub carrier).

As described above, an adequate modulation system and the number of subcarriers to be assigned can be determined from the bit rate and QoS, and the symbol rates of all subcarriers can be set to the same rate, 15 kHz.

As described above, subcarriers and a modulation system are assigned for every communication channel, and 512 complex data symbols (at the symbol rate of 15 kbps) in total are obtained. In this case, if a communication channel is insufficient and a sub carrier is surplus, the sub carrier can be made not to be modulated, that is, to be a complex number (0+j0).

Thus, the sequence of the alignment of 512 pieces of parallel complex data obtained in this manner is replaced by the randomizer 104. This operation is performed per symbol. The randomizer 104, as shown in FIG. 4, replaces the sequence every symbol with a control signal (for example, 8 bits). If the control signal is 8 bits, 256 kinds of replacement can be performed. In FIG. 4, although the input signals X510 and X511 are connected to Y510 and Y511 as it is, this supposes the control channel.

The control channel is to transmit symbol synchronization and information about a randomization pattern to the receiving side. Hence, it facilitates an initial access to transmit it as it is without performing randomization.

The discrete inverse Fourier transformer 105 processes 512 pieces of randomized parallel complex data A' to obtain 512 sets of I and Q parallel data B. The parallel/serial converter 106 converts this result into a serial signal C. The parallel/serial converter 106 makes a real part before transformation be an I signal, makes an imaginary part be a Q signal, and outputs them to the transmitter 107 at the sample rate of 15 ksps×512 = 7.68 Msps. The transmitter 107 performs the orthogonal modulation of the I and Q baseband signals, and outputs them from the antenna 115.

FIG. 12 shows the allocation of the subcarriers in a transmitter signal. As shown in FIG. 12, each interval between subcarriers is equal to 15 kHz that is the symbol rate, and the number of subcarriers is 512. Therefore, bandwidth is 15 kHz×512 = 7.68 MHz.

Next, the operation of the receiving side will be described. The receiving side receives the high frequency signal transmitted from the transmitting side with the antenna 116, and performs orthogonal demodulation with the receiver 108 to generate a baseband signal (I and Q) D. The receiving side samples this at the rate of 7.68 Msps with the serial/parallel converter 109 respectively to generate a parallel signal E that consists of 512 sets of I (real part) and Q (imaginary part) signals. The discrete Fourier transformer 110 receives this signal to output 512 complex numbers.

These data F' express signal points of corresponding subcarriers on a complex plane. The de-randomizer 111 receives

this result, and restores the sequence of the subcarriers that is changed in the randomizer 104.

The de-randomizer 111 replaces the sequence per symbol with the control signal (for example, 8 bits), as shown in FIG. 5. If the control signal is 8 bits, 256 kinds of replacement can be performed. In FIG. 5, although the input signals Y510 and Y511 are connected to X510 and X511 as it is, this supposes the control channel.

The control channel is to transmit symbol synchronization and information about a randomization pattern to the receiving side. Hence, it facilitates an initial access to transmit them as they are without performing randomization.

The result F of the de-randomization expresses signal points of corresponding subcarriers on a complex plane. The corresponding bit data is restored from these signal points and the modulation systems of respective subcarriers, and is decoded and outputted to the original signals Y1 and Y2, ..., Yn with the parallel/serial converters 112, 113, and 114.

Thus, it becomes possible by performing the above processing operation to transmit a plurality of communication channels, whose bit rates and QoS are different from one another, via one OFDM line.

FIG. 9 is a block diagram showing the structure of an orthogonal frequency division multiplex modem circuit according to another embodiment of the present invention. In FIG. 9, the structure of the orthogonal frequency division multiplex modem circuit with a single channel is shown.

That is, the orthogonal frequency division multiplex modem circuit according to this embodiment of the present invention comprises a transmitting side consisting of a serial/parallel converter (S/P) 101, a randomizer 104, a discrete inverse Fourier transformer (IFFT) 105, a parallel/serial converter (P/S) 106, and a transmitter (TX) 107, and a receiving side consisting of a receiver (RX) 108, a serial/parallel converter (S/P) 109, a discrete Fourier transformer (FFT) 110, a de-randomizer 111, and a parallel/serial converter (P/S) 112.

The orthogonal frequency division multiplex modem circuit according to embodiment of the present invention is primarily intended to transmit a plurality of communication channels with different bit rates and QoS via one OFDM line. However, with depending on the case, only one communication channel can be passed preferentially.

For example, when it is necessary to relay digital Hi-Vision TV broadcasting, it becomes necessary to assign all subcarriers to this. In such a case, it is also conceivable to stop other communication channels with lower priorities temporarily and to use all subcarriers for one preference channel. Hence, the orthogonal frequency division multiplex modem circuit according to this embodiment of the present invention has the above-described structure.

Thus, the present invention includes also adaptively determining the assignment of subcarriers and modulation systems according to the priorities, bit rates, and QoS of communication channels.

Moreover, it is not desirable that difference of mean signal power arises between the subcarriers whose modulation systems differ. The present invention includes also making the mean signal power of all subcarriers uniform by adjusting peak values of symbols.

As described above, the present invention has an advantage that, the orthogonal frequency division multiplex modem circuit which uses a plurality of subcarriers for communication, and transmits and receives a plurality of communication channels can multiplex and transmit signals, whose bit rates and QoS are different from one another, via one OFDM line by assigning each of subcarrier groups, into which the plurality of subcarriers is divided, to each of the plurality of communication channels.